ATLAS - A NEW PULSED POWER TOOL AT LOS ALAMOS NATIONAL LABORATORY

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Abstract

The Atlas pulsed power driver has recently been commissioned at Los Alamos National Laboratory. This paper provides an overview of the Atlas facility, its initial experimental program and plans for the future. The reader desiring more detailed information is referred to papers in this conference by Keinigs et al. on materials studies, Cochrane et al.on machine performance and Ballard et al. on fabrication and assembly. Atlas is a high current generator capable of driving 30 megamps through a low-inductance load. It has been designed to require minimal maintenance, provide excellent diagnostic access, and rapid turnaround. Its capacitor bank stores 23.5 megajoules in a four-stage Marx configuration which erects to 240 kV at maximum charge. It has a quarter-cycle time of 4.5 microseconds. It will typically drive cylindrical aluminum liners in a z-pinch configuration to velocities up to 10 mm/μsec while maintaining the inner surface in the solid state. Diagnostic access includes 360° of radial view as well as axial views from above and below. The photograph shows the circle of tanks containing capacitor banks, the diagnostic platform and load area. Atlas construction began in 1996 and high-current acceptance tests were completed in December of 2000. Initial shots include liner characterization shots using a target design similar to NTLX experiments (see several papers by Turchi et al., this meeting). These will be followed by experiments studying hydro features, useful for validating hydrodynamic algorithms used in weapons computer codes. DOE plans to relocate the Atlas generator to the Nevada Test Site as early as 2002, where it will continue its experimental program supporting the Stockpile Stewardship program and other users.

I. MACHINE CAPABILITIES

The Atlas pulsed power generator provides the largest current pulses, 30 megamps, of any fast capacitor bank in

Figure 1. The Atlas generator consists of twelve capacitor bank tanks surrounding a central target chamber.

the world. When driving a low-inductance load, the current rises to its peak value in 4.5 microseconds. It is designed to drive solid metal liners at implosion velocities exceeding 10 km/sec while maintaining an unmelted inner surface. The Atlas capacitor bank stores 23.5 megajoules with a peak voltage of 240 kV. It has an overal system inductance of 18 nH with a typical load configuration.

Atlas was built by the Department of Energy's

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14. ABSTRACT

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Science-Based Stockpile Stewardship Program. It will provide an experimental capability to investigate a number of phenomena of interest to the weapons design community. These include material properties such as spall strength, friction, strength at high strain and strain rate as well as hydrodynamic behavior of strong shocks in a variety of geometries and materails. These experimental data will support the develpment and improvement of physical models used in large-scale computer simulations.

DOE encourages potential users from the academic community to explore other possible scientific applications for Atlas. In addition to the subjects discussed above, high magnetic field generation and magnetized target fusion are possible applications of this technology.

The unique characteristics which Atlas brings to this endeavor include large experimental volumes of several cubic centimeters, large delivered energies of 2 to 6 megajoules, converging geometry, precision control of liner velociy, position and timing, and excellent diagnostic access. The generator requires minimal maintenance enabling it to support a shot rate up to 100 shots per year.

II. MACHINE DESIGN

The Atlas capacitor bank consists of 384 high-energy-density capacitors manufactured by Maxwell Laboratories (now GA Technologies). These 34 microfarad capacitors each store 60 kilojoules at 60 kilovolts. They are arranged into 96 Marx banks each consisting of four

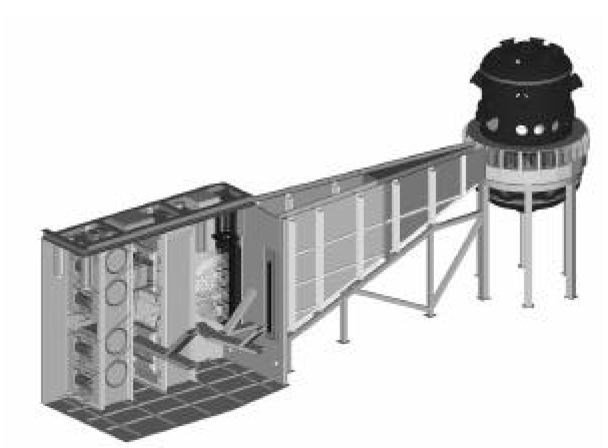

Figure 3. This cutaway shows one MU mounted in an oil tank connected to its load protect switch and vertical transmission line.

capacitors discharged in series through Maxwell railgaps. These railgap switches reliably provide 20-25 discharge channels in parallel for low inductance operation. They are filled with a gas mixture consisting of 15% sulfur hexaflouride and 85% argon.

The mechanical assembly of the Atlas capacitor bank consists of combinations of four Marx modules mounted in 24 so-called “maintenance units,” or MUs. These can be individually removed from the machine for maintenance or service, providing a modular system. A 25th MU is available to swap into the machine in exchange for one with a fault or for routine maintenance.

The MUs are mounted in twelve tanks filled with dielectric oil for high voltage insulation. The current discharge from each MU passes through a load-protection switch, then through an oil-insulated transmission line, a disk-line current collector and finally the load in the center of the machine. During capacitor charging the load-protection switches are kept in a closes position which shorts the capacitor output to ground. At charge complete the load protection switches are quickly opened, allowing current to flow into the transmission lines and load.

The 24 transmission lines are aluminum triplates immersed in oil for high-voltage insulation and held together with nylon insulator posts. They are mounted with their short axes vertical. This allows a large current-carrying area to be brought close to the load region in order to minimize overal system inductance. Each one is twenty feet long and tapers from five feet high at the capacitor end to 15 inches high at its inboard end.

The transmission lines connect to a six-foot-diameter hub. This transition section forces the current to redistribute from the vertical faces of the transmission lines and merge in a horizontal disk and cone line. The disk and cone power flow channel uses solid dielectric for insulation (polyurethane and polyethelene) which extends

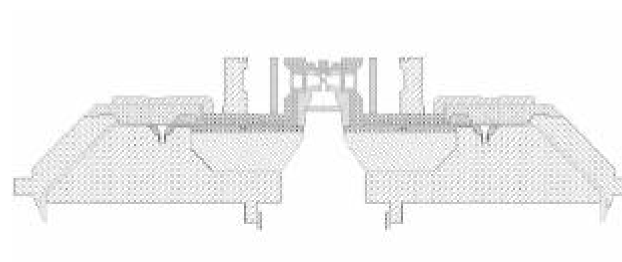

Figure 2. A disk and cone current feed with solid dielectric insulation delivers the current to the cylindrical load. Massive blocks prevent the conductors from separating during the discharge.

to the load cylinder.

The cylindrical liner used for the load is mounted with its axis vertical in the center of the machine elevated about 18 inches above the tops of the oil tanks. It is typically made from 1100 aluminum, 8.5 centimeters in diameter, 4 centimeters tall and one to two millimeters thick, although any of these dimensions can be modified through a broad range to suit the experiment.

A six-foot diameter, six-foot tall vacuum/debris chamber is mounted over the target. Diagnostic access to the bottom of the target is also provided through a lower vacuum chamber.

III. PLANNED EXPERIMENTS

Other papers at this conference describe several experiments being prepared for Atlas in detail. Here we provide a brief overview of some typical experiments to provide a flavor for the Atlas experimental program.

Friction between different materials under the highly dynamic conditions created by strong shockwaves is poorly understood under many conditions. In one series of planned experiments, an Atlas liner will strike a target consisting of rings of different materials pressed together. As the resulting shock wave moves through a less dense material, it will tend to outrun the nearby shockwave in its denser neighbor. Friction at the interface between the two materials will tend to cause one to be dragged back while the other is pulled ahead. Stop-action pictures of this process will be taken using short-pulse x-ray sources. The distortion of the low-density material near the interface will be made visible by embedding pins made of denser material perpendicular to the interface. The curvature of the pins will provide valuable information about the magnitude and development of friction at the interface.

The behavior of a strong shock wave as it passes through a complex geometry can be quite difficult to calculate with computers. Figure 4 illustrates an experiment performed on Pegasus, the predicessor to Atlas, demonstrating the complex behavior of a shock wave encountering an asymmetrical feature. The target consisted of two half-cylinders of different radii of liquid galium imbedded in a lucite cylinder. As a shock wave passed through the junction of the unmatched galium

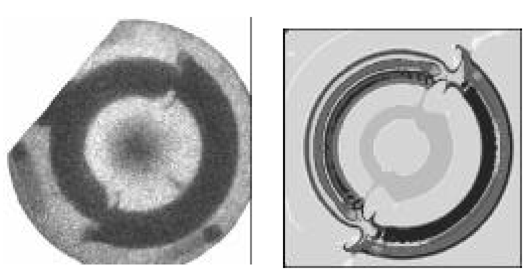

Figure 5. Comparison of shock waves moving through a complex geometry, experiment (on Pegasus) and computer simulation.

cylinders, it generated the complex roll-ups observed in the radiograph and matching calculation. This problem is serving as a test case for hydrodynamic code testing. Similar experiments on Atlas will extend parameter range of available for experimental comparisons.

When a strong shockwave passes through a solid material with strength and encounters a free surface, the reflected wave is a release wave which can produce negative pressures in the material. If the magnitude of the negative pressure exceeds the strength of the material, the material will tend to spall, leading to bulk damage. The spall strength and nature of the spall damage are important in dynamic situations. Spall experiments on Atlas will consist of an Atlas liner striking an inner target liner. End-on radiographs will capture the location, shape and density of the spall layer as the release waves moves from the inner free surface of the target cylinder back toward the outside.

A solid material undergoing rapid deformation resists that deformation due to its strength. As a result, the material will heat. An experiment can be designed so that the deformation heating is the only effect heating the inner surface of an imploding liner. The experiment illustrated in Figure 5 measures the temperature rise of the inner surface using infrared pyrometry.

These sample experiments illustrate several of the experimental diagnostics available for Atlas experiments.

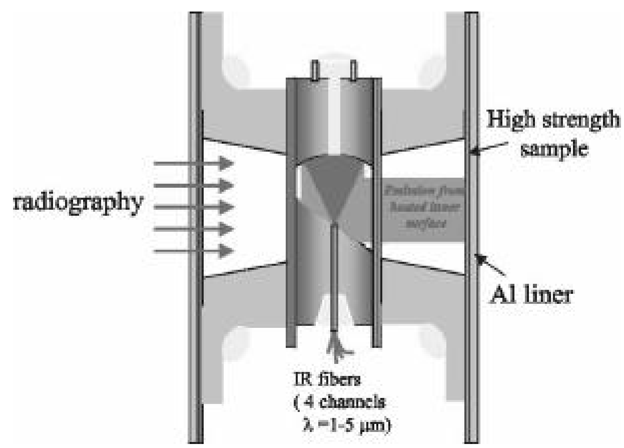

Figure 4. A liner being imploded in Atlas undergoes deformation heating. Pyrometry will be used to measure the temperature rise of the inner surface.

In addition to x-radiography and pyrometery, existing diagnostics include visar, to measure the velocity of the inner surface of the liner and/or targets, visible axial backlighting, for targets with transparent components, and a variety of electrical diagnostics. It is anticipated that many experiments will be accompanied by development of new diagnostics appropriate to the phenonenon under study.

IV. ATLAS PLANS

Construction of the Atlas generator was completed in calendar 2000. Test shots demonstrated its ability to deliver current pulses up to 28.7 megamps into a static inductive load. The project was completed on schedule and cost less than its original budget.

The first experiments on Atlas will be fired in July, 2001. The first shots will demonstrate Atlas' ability to drive a symmetrical liner implosion. These shots will be followed soon after by experiments studying hydro

features (extending the Pegasus experiments in Figure 5). Within the next year we anticipate performing experiments on friction and spall.

The Department of Energy is pursuing plans to relocate the Atlas experimental facility to the Nevada Test Site. Los Alamos National Laboratory will continue to play a leading role in the experimental program on the facility, but participation is expected by researchers from other national laboratories and the academic community.

A building is being built at the Nevada Test Site to house Atlas. It is anticipated that midway through fiscal year 2002 the Atlas generator will be disassembled from its current home in Los Alamos, moved to Nevada, reassembled and recommissioned. The experimental program should recommence in about the middle of fiscal year 2003.